A Quantitative Analysis of the Close Central Vowel [ɨ] in the Nakachi Dialect of Irabu Ryukyuan

Determining its Phonemic Status based on its Distribution[1)]

ELMER Patrick

Visiting Researcher, National Museum of Ethnology

Summary

In this study, the phonemic status of the close central vowel [ɨ] in the Nakachi dialect of the Southern Ryukyuan language of Irabu is examined. This study focuses on quantitative phonological analysis to clarify the distribution of [ɨ] and phonetically similar sounds in relation to the preceding and following phonetic environments and the position in the word. The distribution of the relevant sounds [i], [ɨ], [ʂ], and [ɪ] are examined using a large set of data from a dictionary (Tomihama 2013). This study demonstrates how distributional analysis can be conducted computationally. The results confirm the general distribution of sounds in the Nakachi dialect, as shown by Tomihama (2013), and provide objective evidence that the close central vowel [ɨ] is an allophone of /i/.

Key words: Proto-Ryukyuan, Irabu language, close central vowel, phonemic analysis, computational linguistics

1. Introduction

The purpose of this study is to examine the phonemic status of the close central vowel [ɨ] in the Nakachi dialect of the Southern Ryukyuan language of Irabu. Specifically, the environments where [ɨ] and phonetically similar sounds [i, ʂ, ɹ] occur and their relative distributions in relation to one another are quantitively examined. Based on the results, it is discussed whether [ɨ] belongs to the same phoneme as [i], [ʂ], or [ɹ]. All 17,300 lexical items listed as entries in a dictionary of the language (Tomihama 2013) were used for the analysis.

Regarding the study strengths and contributions, the quantitative analysis of the data makes the process of analysis transparent and objective. The amount of lexical data processed is much larger than that typically processed in a descriptive study; thus, it is possible to compare all the phonetic environments of each pair of phonetically similar sounds in the corpus. The results not only confirm some of Tomihama's (2013) analysis but also help identify some inconsistencies between the previous claims and the actual data.

The Irabu language belongs to the Japonic language family, which consists of the Ryukyuan and Japanese branches. The Ryukyuan branch of the Japonic language family consists of two major subgroups (Fig. 1): Northern Ryukyuan, consisting of Okinawa and Amami, and Southern Ryukyuan, consisting of Miyako, Yaeyama, and Yonaguni[2] (Lawrence 2008: 65; Pellard 2013: 81; Karimata 2015: 115). The Ryukyuan languages are spoken on the Ryukyu Islands (Map 1). According to

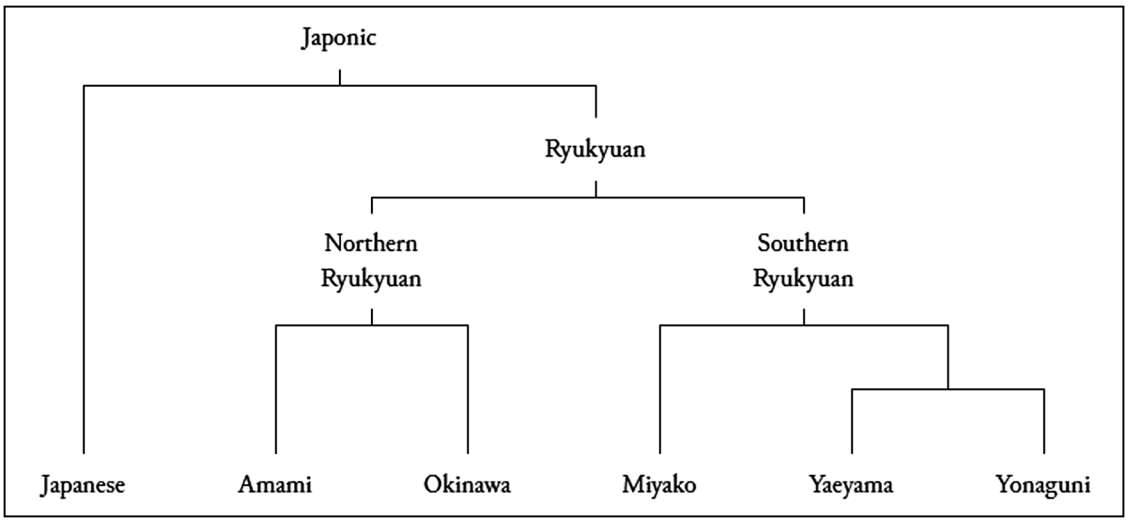

Fig. 1 Phylogenetic tree of the Japonic language family

Shimoji (2008), the Irabu language examined in this study is spoken on Irabu Island and belongs to the Miyako languages of southern Ryūkyū. The Irabu language is divided into three dialects: Sawada-Nagahama, Kuninaka, and Irabu-Nakachi (Shimoji 2008: 24). These dialects are named after the districts in which they are spoken. The names of the districts of Irabu Island are presented in Map 2. The dialect spoken in the districts of Maezatozoe and Ikemazoe is not considered part of the Irabu language. This is referred to as the Sarahama dialect, which belongs to the Ikema language spoken on the nearby island of Ikema (Hayashi 2013: 2, 4–5; Shimoji 2008: 24).

In this research, the status of the close central vowel [ɨ] is examined based on data of the language spoken in the Nakachi district shown in Map 2, which corresponds to what Shimoji (2008) refers to as the Nakachi-Irabu dialect. This dialect is referred to as the Nakachi dialect in this paper.

The vowel [ɨ] has been analyzed in various ways in previous research on different Southern Ryukyuan languages. In the Miyako languages spoken in Ōgami, Tarama, and Ikema, and in the Nagahama dialect spoken in Irabu, it is considered an independent phoneme. In the Nagahama dialect of Irabu, the phoneme is transcribed with the symbol /ï/ and its allophones as [ɨ, ɯ] (Shimoji 2008: 71). The minimal pair of [sɨta] "tongue" and [sata] "sugar" is given and it is mentioned that /ï/ occurs only after the fricatives /s, z, ts, f/ (Shimoji 2008: 39–41). In Ikema, the vowel /ɨ/ is also said to occur only after the same fricatives /s, z, ts, f/ (Hayashi 2013: iv, 48, 57–58, 183). In Tarama, it is mentioned that /ɨ/ is phonemic and developed from *i (Aoi 2016: 9). There are four allophones of /ɨ/, which are transcribed as [^{s}ɨ, ^{z}ɨ, ʂ, ɨ] (Aoi 2016: 43). In Ōgami, the pronunciation is further back than in other Miyako languages and transcribed as /ɯ/ (Pellard 2009: 37). The contrast with all other vowels is demonstrated by minimal pairs (Pellard 2009: 39).

A major concern regarding the status of [ɨ] of the Miyako languages involves morphophonological aspects, and comprehensive analyses have been conducted on this subject. A commonly known morphophonological phenomenon is words ending in /ɨ/ behaving like consonant-final words when followed by the accusative or nominative clitic (Pellard and Hayashi 2012: 23). For the Nagahama dialect, Shimoji proposes an /ɨ/-insertion rule to solve this problem, where /ɨ/ is not present in the underlying representation of a word, but is inserted as an epenthetic segment when a word would not be phonotactically well-formed (Shimoji 2007: 73). A related issue is whether [ɨ] should be treated as a vowel or a syllabic consonant [ʂ] in Miyako languages (Pellard and Hayashi 2012: 22). It has been pointed out that this issue can be resolved for each dialect based on its phonological system, but limited phonological studies have focused on this aspect (Pellard and Hayashi 2012: 22). These morphophonological phenomena constitute one of the important issues in the analyses of Ryukyuan languages. However, the focus of the present study is to develop a computational methodology and examine the distribution of relevant sounds. How morphophonological phenomena can be dealt with quantitatively is beyond the scope of this study and remains a topic for future research.

When we consider the distribution of sounds, it is commonly known and accepted that the sound [ɨ] (written [ï] in Tomihama's (2013) work) occurs mostly after sibilants in Miyako languages. The table presenting the syllables provided by Tomihama (2013: x, cited as Fig. 2) shows that [i] does not occur in those environments, suggesting that [ɨ] and [i] could be in complementary distribution.

a あ	i い	ʑi イ	u う	ɯ	e え	o お				
ka か	ki き			kɯ ク	ke け	ko こ	kja きゃ	kju きゅ	kjo きょ	kwa くゎ
ga が	gi ぎ			gɯ グ	ge げ	go ご	gja ぎゃ	gju ぎゅ	gjo ぎょ	gwa ぐゎ
sa さ		sï す	su すぅ			so そ				
	ʃi し				ʃe しぇ		ʃa しゃ	ʃu しゅ	ʃo しょ	
za ざ		zï ず	zu ずぅ			zo ぞ				
	dʒi じ				dʒe じぇ		dʒa じゃ	dʒu じゅ	dʒo じょ	
	ʒi ジ				ʒe ジぇ		ʒa ジぁ	ʒu ジゅ	ʒo ジょ	
ta た	ti てぃ		tu とぅ		te て	to と	tja てゃ	tju てゅ	tjo てょ	
tsa つぁ		tsï つ	tsu つぅ			tso つぉ				
	tʃi ち				tʃe ちぇ		tʃa ちゃ	tʃu ちゅ	tʃo ちょ	
da だ	di でぃ		du どぅ		de で	do ど	dja でゃ	dju でゅ	djo でょ	
na な	ni に		nu ぬ		ne ね	no の	nja にゃ	nju にゅ	njo にょ	
ha は	hi ひ		hu フ		he へ	ho ほ	hja ひゃ	hju ひゅ	hjo ひょ	
ba ば	bi び	bʷi ビ	bu ぶ		be べ	bo ぼ	bja びゃ	bju びゅ	bjo びょ	
pa ぱ	pi ぴ	pʷi ピ	pu ぷ		pe ぺ	po ぽ	pja ぴゃ	pju ぴゅ	pjo ぴょ	
fa ふぁ	fi ふぃ		fu ふ		fe ふぇ	fo ふぉ	fja ふゃ			
va ヴぁ	vi ヴぃ		vu ヴぅ				vja ヴゃ			
ma ま	mi み	mʷi ミ	mu む		me め	mo も	mja みゃ	mju みゅ	mjo みょ	
ja や			ju ゆ		je いぇ	jo よ				
ra ら	ri り		ru る		re れ	ro ろ	rjo りゃ	rju りゅ	rjo りょ	
wa わ										
n ん										
ŋ ん										
m̩ ン										
v̩ ヴ										
ʔ ʳ	グロッタルストップ（喉頭破裂音）は伊良部・仲地方言の大きな特徴である。									
促音 っ										
長音 ː										

Fig. 2 Table presenting the syllables of the Nakachi dialect (Tomihama 2013: x)

Nevertheless, a comparison of the distribution of [ɨ] and [i] to investigate this aspect has not been published. Addressing these gaps in prior research, the current study involved a detailed analysis of the phonological system of the Nakachi dialect using a large amount of data, to verify if a complementary distribution of [ɨ] and [i] is in fact coherent across the data.

The remainder of this paper is organized as follows. In Section 2, the language data of the

Nakachi dialect and other dialects of Irabu are introduced. In Section 3, the specific research questions of this study are presented, and the orthography system used in this study is explained. Section 4 presents the procedure for determining the phonemic status of sounds based on the phonetic environments in which these sounds occur. In Section 5, the procedure described in Section 4 is applied to [ɨ] and phonetically similar sounds. The results are presented and discussed in Section 6.

2. Language data

In this section, the language data of the Nakachi dialect and its phonemic analysis reported in Tomihama's prior work are presented.

The dictionary of the Nakachi dialect of Irabu used as the source of the lexical items in this study is Tomihama's (2013) work. Tomihama, the compiler of the dictionary, is a native speaker of the Nakachi dialect of Irabu, born in 1929. The dictionary contains 17,300 headwords in Kana syllabary, phonetic transcriptions, conjugation types, and explanations of the word meanings (Tomihama 2013: i, vii). The dataset used in this study contains 20,998 words. This is because some lexical items, such as phrases consisting of more than one word, were split into multiple words for the purpose of analysis. A digitized version of the dictionary compiled by Karimata (2022) was used in this study.

Tomihama explicitly lists 7 vowels /a, i, ᶻi, u, ɷ, e, o/, 2 semivowels /j, w/, and 20 consonants /k, g, t, d, s, ts, z, ʃ, ʒ, tʃ, dʒ, p, b, f, v, h, r, n, ŋ, m/ as phonemes (Tomihama 2013: xi). In addition, the dictionary includes a table in which all the syllables of the Nakachi dialect are listed, as shown in Fig. 2. The way phonemes are analyzed by the compiler can be inferred from this table.

Of the four sounds [ï, ˢï, ᶻï, i] relevant to this study, [ᶻï] occurs as a vowel and following [b, m], while [ˢï] occurs only following [p]. [ᶻï] and [ˢï] contrast with [i] in this environment. Meanwhile, [ï] occurs only following [s, z, ts], whereas [i] occurs in all other environments, suggesting that [ï] and [i] are in complementary distribution. Accordingly, this study examines whether [ï] and [i] are, in fact, in complementary distribution across all the items listed in the dictionary. In addition, the distributions of [ˢï] and [ᶻï] are also compared with [ï] and [i].

Another observation relevant for this study is the phonemic distinction between the post-alveolar sibilants [ʃ, dʒ, ʒ, tʃ], which occur after the five vowels [a, i, u, e, o], and the alveolar sibilants [s, z, ts], which occur after [a, ï, u, o]. Post-alveolar sibilants do not occur before [ï] and alveolar sibilants do not occur before [i].

While the data shown above constitute the only information available from a detailed study on the Nakachi dialect, previous research has extensively studied related dialects spoken on Irabu Island. As other dialects from Irabu Island share many characteristics with the Nakachi dialect, a short overview is provided below.

Data from the fieldwork conducted by Russian linguist Nikolay Nevskiy have recently been translated into English (Jarosz 2015). Linguistic data were mostly collected during a field trip in 1922 (Jarosz 2015: 45). Of the Miyako languages, the data contain 1,466 lexical items of the Sawada dialect, 85 of Irabu (settlement), 25 of Kuninaka, 19 of Irabu-Nakachi, and 18 of Nagahama, in addition to 246 words common to all Miyako languages (Jarosz 2015: 56–57). Further, Shimoji published 199 words of the Nagahama dialect of Irabu (Shimoji 2007). Additional data on the Nagahama dialect have been published as part of a dictionary

of Miyako languages (Hirayama 1983) and works of grammar of Irabu Ryukyuan (Shimoji 2008, 2017, 2018). Other published language data include 830 words of the Kuninaka dialect and 837 of the Irabu dialect (Nakamatsu 1999). In addition, there are 216 words of the Nagahama dialect (Pellard 2009), as well as 88 lexical items of Kuninaka and 103 of Irabu (Pellard and Hayashi 2012).

3. Orthography and research questions

This section begins with an overview of the relevant phonetic aspects of the Nakachi dialect and the analyses of other Miyako languages and Japanese conducted in previous research, and explains the orthography used in this study. Then, the three research questions examined in this study are presented.

In quantitative analysis, it is important to make the orthographic system analyzable and comparable with other language data. For phonetic transcription, symbols in the original language data were converted to the latest IPA (International Phonetic Alphabet) equivalent for the purpose of generalization and possible comparison with other language data (IPA 2020). To process the Nakachi dialect data, such replacements were implemented based on the pronunciation of each sound provided in Tomihama's (2013) work as well as comparisons with closely related dialects and Japanese when necessary. However, some phonetic values remain controversial and need to be verified in future studies.

The transcription system used in Tomihama's (2013) work uses the old IPA symbols "ɷ" and "ɨ" (Udomkesmalee 2018), and these are replaced with the IPA symbols [ʊ] and [ɨ] in this study. Other sounds that are described as pronounced in the same way as in Japanese (Tomihama 2013: xi–xvi) have been replaced with the IPA symbols accordingly. Such sounds are alveolo-palatal consonants and the tap, which are transcribed in Tomihama's work as [tʃ, dʒ, ʃ, ʒ] and [r], respectively. These are replaced with [t͡ɕ, d͡ʑ, ɕ, ʑ], and [ɾ], with tie bars used for affricates according to the IPA specification (IPA 2020). Another such sound is the consonant "w," which corresponds to the Japanese sound that has been described as a voiced bilabial approximant in a recent paper (Maekawa 2020). The IPA does not specify a symbol for the voiced bilabial approximant, but it can be transcribed using diacritics as an advanced voiced labiodental approximant [ʋ̟].

As for the close central vowel [ɨ] ([ï] in Tomihama's (2013) work), which is the focus of this study, acoustic analysis of formants has shown that the symbol "ï" is used to transcribe several different phonetic values in various southern Ryukyuan dialects (Ōno et al. 2000: 34). This indicates that this vowel is realized in different ways. In Tomihama's (2013) work, in addition to the symbol "ï," there are two sounds transcribed using the non-IPA superscript fricatives "ˢ" and "ᶻ"

Table 1 Comparison of different phonetic transcriptions

Nagahama dialect (Shimoji 2006)	Nagahama dialect (Shimoji 2007)	Nakachi dialect (Tomihama 2013)	Nakachi dialect (this research)
[ɿ]	[ɨ]	[ï]	[ɨ]
[ˢɿ]	[ʂ]	[ˢï]	[ʂ]
[ᶻɿ]	[ʐ]	[ᶻï]	[ɹ]
[l]	[l]	[ᶻï]	[ɹ]

that precede the symbol "ï." The phonetic value of these non-IPA transcriptions is not explicitly given in Tomihama's (2013) publication, and the symbols used in this study for these sounds were decided based on correspondences to the description of the Nagahama dialect of Irabu language by Shimoji (2006, 2007). Shimoji (2006, 2007) presents a detailed analysis of the sounds transcribed as [ɻ, ˢɻ, ᶻɻ, ɭ] (2006), or [ɨ, ʂ, ʐ, ɭ] (2007). These sounds are considered to correspond respectively to [ï, ˢï, ᶻï, ᶻí] in the Nakachi dialect as represented by Tomihama (2013). The correspondences are listed in Table 1, along with the symbols used in this study.

As for the phonetic value of these sounds, Shimoji explains that the retroflex lateral [ɭ] in the Nagahama dialect corresponds to a "[z]-like approximant (or [z] with a less friction)" in the Nakachi dialect (Shimoji 2008: 25). For example, Nakachi [paʐ] "the needle" corresponds to Nagahama [paɭ]. Tomihama (2013) transcribes the same word as [paᶻï] in the Nakachi dialect. Based on these correspondences given by Shimoji, the symbols used in this study were determined based on the following. It can be assumed that the IPA transcription [ʐ] for [ᶻí] may be correct for the Nakachi dialect as well. Shimoji further states that [ʐ] "is meant to cover a range of sounds from [z] with less friction to a [z]-like approximant" (Shimoji 2008: 38) and is not the voiced counterpart of [s] (Shimoji 2006: 39). According to the latest IPA (2020), an approximant that otherwise shares all features with [z] is transcribed as [ɹ]. Although the actual phonetic value of [ᶻí] could only be verified with a speaker, following the above, the symbol [ɹ] was used in this research.

Regarding Tomihama's [ˢí], the symbol for the lowered voiceless alveolar fricative [ʂ] was used. Shimoji (2007) analyzes [ʂ] in Nagahama as the unvoiced counterpart of [ɹ]. This sound has been described differently in other languages of the southern Ryukyuan Islands. For example, the word for "person" has been transcribed as [pʂtu] in the Nagahama dialect (Shimoji 2008: 44) and the Aragusuku dialect spoken on Miyako Island (Wang 2022: 125). In the Ōgami dialect, it has been transcribed as [pstu] (Pellard 2009: 37) and in the Tarama dialect as [pʂtu] (Aoi 2016: 43). However, Hayashi points out that the lack of lip rounding cannot be explained by the fricative [s], and therefore suggests the transcription of a voiceless vowel [pˢi̥tu] in Miyako dialects (Hayashi 2013: 48, footnote 54). Again, with confirmation of the actual value of this sound in the Nakachi dialect pending, the symbol [ʂ] was used in this research based on the assumption that it corresponds to the Nagahama dialect.

The symbols used in this study that reflect the above discussion are presented in Tables 2 and 3. Table 2 lists the vowels from the language data of the Nakachi dialect. In addition to what has been discussed above, diacritics are used to transcribe the close front unrounded vowel [e̝], the close back rounded vowel [o̝] and the open central unrounded vowel [a̠]. The vowels in Table 2 are unrounded except for the rounded vowels [o̝] and [ʊ]. Note that [ʊ] is a near-close near-back rounded vowel but has been written in the close back vowel cell for simplicity. All vowels have short and long contrast.

Table 3 lists the consonants from the language data of the Nakachi dialect. If there is a voicing distinction, the voiceless variant is written on the left and the voiced counterpart on the right.

Table 2 Vowel phones of the Nakachi dialect

	Front	Central	Back
Close	i	ɨ	ʊ, u
Mid	e̝		o̝
Open		a̠	

Table 3 Consonant phones of the Nakachi dialect

	Bilabial		Labio-dental		Alveolar		Palatal	Alveolo-palatal		Velar		Glottal
Plosive	p	b			t	d				k	ɡ	ʔ
Affricate					t͡s	d͡z		t͡ɕ	d͡ʑ			
Nasal		m				n					ŋ	
Tap or Flap						ɾ						
Fricative			f	v	s	z		ɕ	ʑ			h
Approximant		ʋ̥			ʂ	ɹ	j					
Lateral appr.						l						

Geminates are transcribed as [mː, nː, vː, zː, ɹː, t͡sː, t͡ɕː, d͡zː].

Based on the literature and perspectives discussed above, the following research questions were formulated.

(1) What is the distribution of the phonetically similar sounds [i], [ɨ], [ʂ], and [ɹ]?

(2) Based on the results addressing question (1), what is the distributional relationship between [ɨ], [ʂ], and [ɹ] and are any of them analyzed to belong to the same phoneme?

(3) What is the distributional relationship between [i] and [ɨ]?

4. Methodology

This section presents the methodology used in this study for computationally determining whether sounds are phonemes. The goal was to process all lexical items from an entire dictionary of the Nakachi dialect so that the phonetic environment in which each relevant sound occurs can be analyzed and compared. The number of lexical items processed in this study was much larger than that typically used in descriptive studies. While this method has advantages, such as the ability to analyze the phonetic environment of all sounds in each recorded word of a dialect or language, it also has some drawbacks. For example, it is not possible to detect every phonological relationship between two sounds with this method because it does not implement complex conditioning factors. Therefore, the results must be carefully examined and interpreted.

The method of phonemic analysis for determining the phonological system of a language is usually carried out based on the steps presented in the flowchart shown in Fig. 3 (Crowley et al. 1995: 103; Hayes 2021: 461). The procedure consists of the following four steps: (1) Setting out phonetically similar sounds; (2) checking for minimal pairs; (3) checking for free variation; and (4) checking for complementary or contrastive distribution. Phonetically similar sounds are sounds that differ in only a few articulatory features and thus often form natural classes (Crowley et al. 1995: 87–88).

The description in Fig. 3 is provided for explanatory purposes and it clarifies the traditional way of applying the methodology. This method was developed to describe phonological systems of languages that are unknown to the researchers, usually carried out by collecting speech data from native speakers during fieldwork. In contrast, the present study analyzed phonemic status based on lexical items using a computer program. As such, although the research goals are identical when

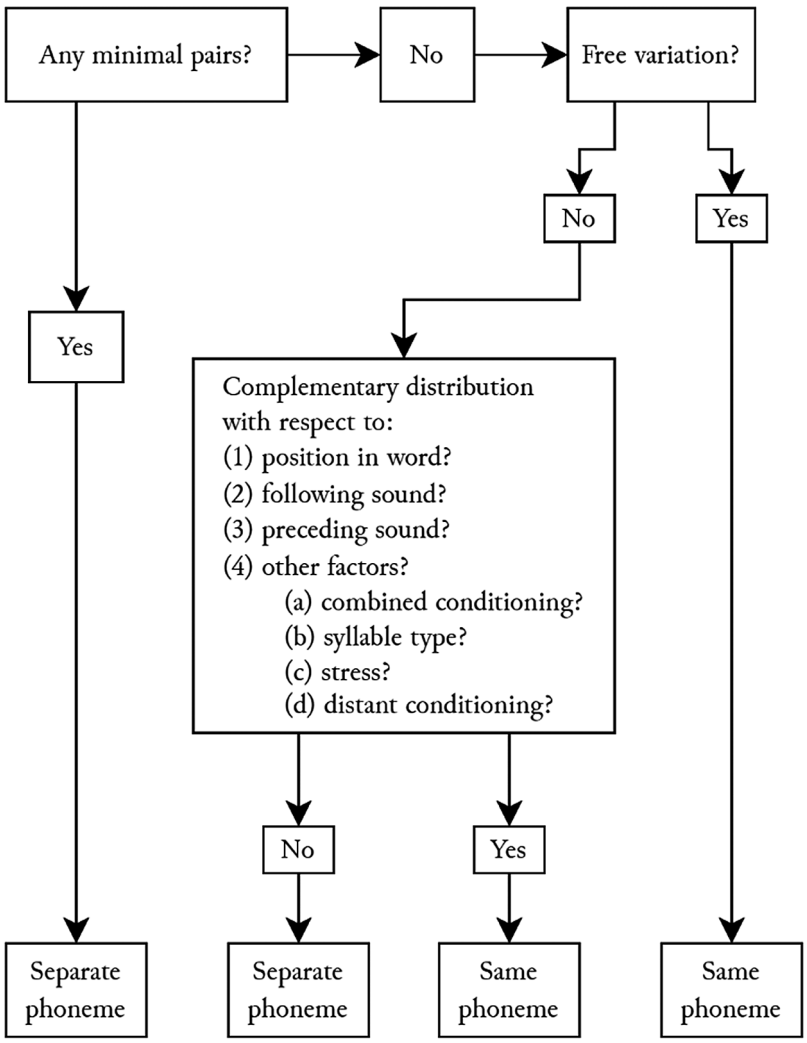

Fig. 3 Flow chart of phonemic analysis (redrawn from Crowley et al. 1995: 103)

employing the two methods, the requirements are quite different. Computers cannot rely on linguistic intuition, nor can they obtain native speaker judgments. In addition, a computational analysis can only be performed once a large amount of phonetically transcribed language data is already available. For this study, it was decided to computationally implement only those parts of the methodology that were well suited for computational analysis. The interpretation of the research results has been performed manually, following the traditional method.

This study focused on the step of checking for contrastive or complementary distribution in particular, carried out based on the phonetically similar sounds selected by the researcher. In terms of conditioning factors, it implements the preceding sound, the following sound, the position in a word, or any combination of them. However, more complex conditioning factors were not implemented. After determining the phonetic environments in which each sound occurs, whether the two sounds are in contrastive or complementary distribution can be determined by comparing the phonetic environments in which both sounds occur. Based on their distribution, sounds can be categorized as belonging to separate phonemes or as allophones of the same phoneme.

The following paragraphs present the general procedure implemented for analyzing the phonemic status of the vowel [ɨ] in this research. The language data were prepared, as outlined in Section 3, by cleaning the data and converting them to IPA transcription.

The following four steps were carried out:

(1) Setting out phonetically similar sounds
(2) Computing the distribution of sounds
(3) Comparing relevant sounds pairs
(4) Determining whether they are in complementary or contrastive distribution

Of these steps, only steps 2 and 3 were performed computationally. The last step required careful manual interpretation of the research results to determine the phoneme status of each sound.

The first step was to identify phonetically similar sounds. The sounds to be compared with [ɨ] were selected according to two principles. First, sounds that differ in only a few features were considered to be similar. Second, different sounds that form sound correspondences in closely related languages were considered to be similar.

The second step was to record the sounds that occurred before and after each analyzed sound, including word boundaries. Phonetic environments were calculated from a list of phonetically transcribed lexical items. The number of instances of all symbols for the sounds and word boundaries preceding and following each sound to be analyzed were added. This resulted in a table of phonetic environments relative to the preceding and following sounds.

In the third step, the phonetic environments of all sound pairs were compared to determine whether the two sounds were in complementary distribution. This was performed for the preceding and following environments, and the results were tabulated. The phonetic environments of each sound were compared by calculating the frequency of occurrence of each of the two sounds in each given phonetic environment.

The fourth and final step was to determine whether the two sounds were in complementary or contrastive distribution. Two sounds are in complementary distribution if exactly one of the two sounds occurs in each possible phonetic environment. This means that for each environment, one of the two sounds should never occur. However, it is expected that there will be words that contradict the general patterns found in the language data. Therefore, some exceptions to the general rules are allowed. If the two sounds are contrastive in all environments with very few exceptions, they can be determined to belong to different phonemes.

The binary distinction between phonemic and allophonic sounds is not always sufficiently detailed for analysis. Language sounds can be categorized on a gradient scale, ranging from phonemic to allophonic or somewhere in between (Goldsmith 1995; Hall and Hall 2016; Scobbie and Stuart-Smith 2008). Four basic distinctions can be made (Hall 2013: 230–32): (1) sounds that are contrastive in all environments are phonemic; (2) sounds that are contrastive in most cases, but complementary in a few environments are "phonologically neutralized"; (3) sounds that are in complementary distribution in most environments, but contrastive in a few environments are "marginal phonemes"; and (4) sounds that are in complementary distribution in all environments are allophonic. In this study, phoneme status was determined based on these four categories.

There are a few caveats to the applicability of this method. First, only phonotactically similar sounds can be compared. For example, comparing

vowels to consonants could lead to false results because both sounds may occur in complementary distribution due to phonotactic constraints. Second, comparing two sounds with defective distribution, that is, sounds that occur in only a very small number of phonetic environments, should be avoided. This is because there are many phonetic environments in which both sounds do not occur; therefore, it is likely that, by chance, the limited environments of both sounds are exclusive, leading to the false conclusion that the two sounds are in complementary distribution.

5. Data analysis

In this section, details of the analysis of the phonetic environments in which the phonetically similar sounds [i, ɨ, ʂ, ɹ] occur are presented. The following subsections detail how the distributions of these sounds were computed and compared to determine their phonemic status. Subsection 5.1 clarifies how the distributions of each sound in relation to the preceding and following sound or word boundaries were computed. The tables in this section have been condensed owing to space constraints. Full tables with all of the data can be found in the Appendix. The research results were then manually evaluated to determine the phonemic status of the analyzed sounds based on the distributions.

5.1 Distribution of [i, ɨ, ʂ, ɹ]

In this subsection, the distributions of the four phonetically similar sounds [i, ɨ, ʂ, ɹ] are examined. The resulting tables aid in comparisons of the distributions of all the sounds. The distributions were computed as follows. All words from Tomihama's (2013) work, as clarified in Section 3, were surrounded by # symbols to indicate word boundaries, and were segmented into individual sounds. Then, the number of occurrences of the sound before and after other sounds and word boundaries were counted, resulting in a list of the number of occurrences of each sound in relation to the preceding and following sounds. A complete table showing the preceding sounds for each analyzed sound is provided in Appendix A, and a table showing the following sounds is provided in Appendix B.

Table 4 shows the 20 most common sounds preceding [i, ɨ, ʂ, ɹ] from Appendix A. Several observations can be made. First, [ɨ] is very rare except after [t͡s, s, z, d͡z]. Second, [i] occurs in most environments, but very rarely after [t͡s, s, z] and never occurs after [d͡z]. Occurrences of [ɨ] after [d͡z] are too rare to be included in Table 4. As can be seen in Appendix A, [ɨ] occurs 71 times and [ɨː] 35 times after [d͡z]. Third, [ɹ] occurs mostly after vowels, bilabial plosives, or at the end of a word. Fourth, [ʂ] occurs only after [p] and never as [ʂː]. Fifth, there is no environment in which all sounds are clearly contrasting. Thus, the distributions must be further evaluated to confirm which sounds are in complementary distribution.

Table 5 shows the 20 most common sounds following [i, ɨ, ʂ, ɹ] from Appendix B. The following observations can be made. First, [ʂ] occurs before the unvoiced consonants [k, t, t͡s, s]. Second, [ɹ] does not occur before [ɾ]. Third, there is no clear pattern of sounds before which [i] and [ɨ] never occur. Fourth, there are several environments in which all the sounds occur, such as the aforementioned [k, t, t͡s, s]. This indicates that all sounds are in contrast based on the following sound. Therefore, the subsections focus on the phonetic environments of [i, ɨ, ʂ, ɹ] in relation to the preceding sounds and analyze which sounds are in complementary distribution.

In the following subsections, the phonetic

Table 4 Number of occurrences of sounds preceding [i, ɨ, ʂ, ɹ] (20 most common environments)

	ɑ̣	t͡s	s	m	k	i	ɾ	z	n	ɛ	t	u	#	g	b	p	d͡z	t͡ɕ	d	ɑ̣ː
_i	1437	2	4	1420	1428	29	1173	5	827	745	590	256	722	677	516	210	353	333	265	31
_ɨ	1	2590	2653	1	4	0	0	1060	0	3	9	0	0	1	0	1	1	0	0	0
_ɹ	1299	0	1	6	0	1266	0	0	2	0	0	650	50	0	123	69	0	0	0	141
_ʂ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	393	0	0	0	0
_iː	2	0	0	300	177	0	41	1	212	211	314	5	39	135	12	22	24	5	28	1
_ɨː	0	147	73	0	0	0	0	143	0	0	0	0	0	0	0	0	0	0	0	0
_ɹː	0	0	7	2	0	0	0	0	0	0	0	0	17	0	118	56	0	0	0	0

Table 5 Number of occurrences of sounds following [i, ɨ, ʂ, ɹ] (20 most common environments)

	#	k	m	ɹ	n	g	t	ŋ	t͡s	b	z	d	ɾ	s	j	f	p	ɛ	v	ɑ̣
i_	3488	825	775	1266	647	470	250	480	314	362	290	332	429	298	218	154	114	196	166	91
ɨ_	2723	731	744	6	341	311	238	87	244	221	129	86	56	22	93	94	93	8	53	30
ɹ_	2671	140	146	1	92	105	100	9	69	41	158	70	0	34	24	50	30	11	9	10
ʂ_	0	45	0	0	1	0	229	1	40	0	0	0	0	69	0	3	1	0	0	0
iː_	706	50	55	10	147	47	42	117	23	30	17	42	29	13	99	15	32	22	6	10
ɨː_	229	15	10	0	20	15	10	2	2	13	20	6	9	5	5	9	11	0	1	5
ɹː_	113	5	18	0	12	2	11	0	1	2	5	0	0	4	3	8	5	0	2	0

environments of each relevant group of sounds are compared, based on Appendix A. Where necessary, more detailed tables are provided. By comparing the distribution of sounds, whether both sounds are in complementary or contrastive distribution is determined, clarifying which phoneme each sound belongs to.

5.2 A comparison of the distribution of [ɨ, ʂ, ɹ]

In this subsection, the distributions of [ɨ, ʂ, ɹ] are compared. First, [ɹ] and [ʂ] are in complementary distribution and thus form a single phoneme. [ɨ] is also in complementary distribution with [ʂ, ɹ]. Owing to its limited distribution, [ɨ] needs to be examined in more detail to determine whether it belongs to the same phoneme. The three sound pairs [ɨ, ɹ], [ɨ, ʂ], and [ʂ, ɹ] are compared in Tables 6, 7, and 8 respectively. The data in these tables are based on the data from Table 4 and Appendix A.

Table 6 compares [ɨ] and [ɹ]. There are several environments in which only one of the two sounds occur. As analyzed in Section 5.1, [ɨ] occurs after [t͡s, s, z, d͡z] and [ɹ] after vowels, bilabial plosives, and word boundaries. In all other environments, neither of the sounds occurs.

There are two possible interpretations for this finding. First, both sounds belong to the same phoneme, with one or more other allophones that occur in the environments where neither [ɨ] nor [ɹ] occurs. Second, the complementary distribution of both sounds is coincidental because of the limited distribution of each sound.

Table 7 compares [ɨ] and [ʂ]. [ʂ] is very rare and occurs only after [p]. Owing to the limited distribution of [ʂ], whether [ɨ] and [ʂ] belong to the same phoneme must be analyzed in more detail.

Table 6 Comparison of sounds preceding [ɨ, ɹ]

	ɑ̣	t͡s	s	m	k	i	ɾ	z	n	ɛ	t	u	#	g	b	p	d͡z	t͡ɕ	d	ɑ̣ː
_ɨ	1	2590	2653	1	4	0	0	1060	0	3	9	0	0	1	0	1	1	0	0	0
_ɹ	1299	0	1	6	0	1266	0	0	2	0	0	650	50	0	123	69	0	0	0	141

Table 7 Comparison of sounds preceding [ɨ, ʂ]

	ɑ̣	t͡s	s	m	k	i	ɾ	z	n	ɛ	t	u	#	g	b	p	d͡z	t͡ɕ	d	ɑ̣ː
_ɨ	1	2590	2653	1	4	0	0	1060	0	3	9	0	0	1	0	1	1	0	0	0
_ʂ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	393	0	0	0	0

Table 8 Comparison of sounds preceding [ʂ, ɹ]

	ɑ̣	t͡s	s	m	k	i	ɾ	z	n	ɛ	t	u	#	g	b	p	d͡z	t͡ɕ	d	ɑ̣ː
_ɹ	1299	0	1	6	0	1266	0	0	2	0	0	650	50	0	123	69	0	0	0	141
_ʂ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	393	0	0	0	0

Table 9 Phonetic environment p_C showing complementary distribution of [ʂ] and [ɹ]

	t	s	k	t͡s	g	ɛ	d	n	ŋ	ɹ	ɾ	z	b	f	m	t͡sː	t͡ɕː	p	v	#	d͡z
pʂ_	229	69	45	40	0	0	0	1	1	0	0	0	0	3	0	2	2	1	0	0	0
pɹ_	1	0	0	0	39	0	16	5	0	0	0	1	5	0	3	0	0	0	1	1	0

Table 8 compares [ɹ] and [ʂ]. Both sounds are clearly contrasting after [p]. This would suggest that both sounds belong to separate phonemes. However, the sounds following [ɹ] and [ʂ] also need to be considered.

In Table 9, the environments of [ɹ] and [ʂ] after [p] in relation to the following sound is compared. Table 9 shows that [ʂ] occurs after [p] before voiceless consonants, while [ɹ] occurs only before voiced consonants. Therefore, both sounds are in complementary distribution.

From the data presented above, it can be concluded that [ɹ] and [ʂ] are in complementary distribution after [p]. [ɹ] occurs if the following consonant is voiced and [ʂ] if the following consonant is voiceless. Thus, both sounds are analyzed as belonging to the phoneme /ɹ/. Owing to its limited distribution, it is concluded that /ɹ/ is a marginal phoneme that occurs in defective distribution. However, a more detailed study of the phonetic value of [ɹ] in each relevant phonetic environment needs to be conducted to better understand the phonemic status of /ɹ/. In the next subsection, whether [ɨ] is also an allophone of /ɹ/ or whether it belongs to another phoneme /i/ is explored.

5.3 A comparison of the distribution of [ɨ, i]

In this subsection, the distributions of [ɨ] and [i] are compared. [ɨ] and [i] are in complementary distribution with respect to the preceding environment. Further, [ɨ] occurs after the sibilants [s, z, t͡s, d͡z] and [i] occurs elsewhere. It can be concluded that [ɨ] and [i] are in complementary distribution and belong to the same phoneme /i/. Conversely, [ɨ] does not belong to /ɹ/.

Table 10 Number of occurrences of consonants preceding [ɨ] and [i] (20 most common environments)

	t͡s	s	m	k	ɾ	z	n	ɛ	t	g	b	p	d͡ʐ	t͡ɕ	d	h	ʐ	d͡z	t͡ɕː	v
_i	2	4	1420	1428	1173	5	827	745	590	677	516	210	353	333	265	117	124	0	94	39
_ɨ	2590	2653	1	4	0	1060	0	3	9	1	0	1	1	0	0	0	2	71	0	0
_iː	0	0	300	177	41	1	212	211	314	135	12	22	24	5	28	23	2	0	0	0
_ɨː	147	73	0	0	0	143	0	0	0	0	0	0	0	0	0	0	0	35	0	0

The results of the analysis of the consonants occurring before [ɨ] and [i] can be seen in Table 10. [ɨ] occurs mostly after [s, z, t͡s, d͡z], while [i] occurs very rarely after these four sibilants but occurs in all other environments. Long vowels behave in the same way. Therefore, [ɨ] and [i] are clearly in complementary distribution. The complementary distribution of [ɨ] and [i] can be quantified based on the research results. In the whole corpus, [ɨ] occurs 6,407 times. In 99.48% of the cases, it occurs in the phonetic environment after the sibilants [s, z, t͡s, d͡z]. In contrast, only 0.09% of the 11,602 occurrences of [i] are in the same phonetic environment. The same is true for long vowels. [ɨː] always occurs after the same sibilants, while [iː] occurs in this environment only 0.06% of the time. Appendix A presents 14 cases where [ɨ] and [i] seem to be in contrastive distribution before [ʔ], but [ɨ] occurs after [ʔ] only when the vowel before the glottal stop was also [ɨ] and [i] only after [ʔ] if the vowel preceding the glottal stop was also [i].

These results confirm the possible complementary distribution of [ɨ] and [i] suggested by the table presenting the syllables in Tomihama's (2013: x) work. The analysis of the data further shows that [d͡z], which is not contained in Tomihama's (2013) table presenting the syllables, occurs before [ɨ], but never before [i] (see Table 10).

From the data analysis, it can be determined that [ɨ] and [i] belong to the phoneme /i/. [ɨ] occurs in the phonetic environment after the sibilants [s, z, t͡s, d͡z] and [i] elsewhere. This phenomenon can be explained as follows. The change from [i] to [ɨ] prevents the palatalization of the preceding sibilants, which commonly occurs before [i]. This ensures that the distinction between the alveolar and alveolo-palatal sibilants listed in Table 11 is maintained. This is consistent with research on a similar phenomenon in Mandarin Chinese, where [i] is "avoided to eliminate a potential chance of palatalization of the preceding coronals, which may obscure distinct cues in frication noise" (Lee-Kim 2014: 278).

In conclusion, the results provide evidence for analyzing the vowels [ɨ] and [i] as belonging to the same phoneme /i/. [ɨ] occurs after the sibilants [s, z, t͡s, d͡z] to prevent the palatalization of the preceding sibilants, which maintains the distinction between alveolar and alveolo-palatal sibilants. [ɨ] also occurs in the environment after [iʔ]. The vowels [ɨ, i, ɨː, iː] occur a total of 19,964 times in the whole corpus and 99.27% of these cases follow the above rules. This is solid evidence that [ɨ] is not phonemic in the Nakachi dialect of Irabu.

6. Conclusion

This study investigated the phonemic status of the close central vowel [ɨ] and phonetically similar sounds in the Nakachi dialect. Three research questions were examined. First, the distribution of the phonetically similar sounds [i], [ɨ], [ʂ], and [ɹ] was explained. It was found that some of the sounds could be in complementary distribution in

Table 11 Phonemic distinction of alveolar and alveolo-palatal sibilants in the Nakachi dialect of Irabu

	Alveolar sibilants				Alveolo-palatal sibilants			
	s	z	t͡s	d͡z	ɕ	ʑ	t͡ɕ	d͡ʑ
_ɑ	1255	376	50	42	157	19	90	57
_i	4	5	2	0	745	124	333	353
_ɨ	2653	1060	2590	71	3	2	0	1
_u	607	115	60	9	67	3	26	61
_ɐ	0	0	0	0	13	0	0	9
_ɒ	17	0	0	1	2	0	3	5

relation to the preceding sound. Second, the distributional relationship between [ɨ], [ʂ], and [ɹ] was analyzed to determine if any of those sounds are analyzed to belong to the same phoneme. It was found that they are in complementary distribution and [ʂ] and [ɹ] belong to the marginal phoneme /ɹ/ that occurs in defective distribution. Its allophone [ʂ] occurs in the environment after [p] and before voiceless consonants. Third, the distributional relationship between [i] and [ɨ] was examined. It was found that [i] and [ɨ] are in complementary distribution and belong to the phoneme /i/. Its allophone [ɨ] occurs after the sibilants [s, z, t͡s, d͡z] to prevent the palatalization of the preceding sibilants, which maintains the distinction between alveolar and alveolo-palatal sibilants.

This study demonstrates how distributional analysis can be conducted computationally. The results confirmed the general distribution of sounds in the Nakachi dialect, as shown by Tomihama (2013). By computationally processing a large amount of data, this study offers a detailed analysis on the distribution of the sounds [i, ɨ, ʂ, ɹ], missing in prior research. It clearly quantifies the distribution, allowing for an objective evaluation of each sound's distributional relationship to indicate the respective phonemic status. Accordingly, this study showed that sounds that were assumed to be either in complementary distribution or in contrast can be confirmed and supported objectively. Based only on the study of phonology, this research provides evidence that the close central vowel [ɨ] is an allophone of /i/. This contributes to a better understanding of the languages in Miyako.

This study raises interesting questions about the historical development of vowels in Southern Ryukyuan. For example, the Nagahama dialect has a distinction between [i], [ʐ], and [ɭ] in the environment V_#, as demonstrated by the minimal triplet [pai] "the south," [paʐ] "the fly," [paɭ] "the needle" (Shimoji 2008). The Nakachi dialect only retains the distinction between [pɑi] "the south," and [pɑɹ] "the fly/the needle." Word-final [ɹ] corresponds to [ʐ] and [ɭ]. The three sounds found in Nagahama are reconstructed in Proto-Miyako as *i for [i], *ɻ for [ʐ], and [ɭ] corresponding to the sequence *rɻ (Pellard 2009). A diachronic study is needed to explain why this distinction was lost in the Nakachi dialect and what sound changes or historical processes contributed to the emergence of [ɹ]. This fact, together with the absence of the /ɨ/ phoneme in the Nakachi dialect, may have significant implications for the reconstruction of the Proto-Ryukyuan vowel system.

Notes

1) I thank Professors Ritsuko Kikusawa and Noboru Yoshioka, and two anonymous reviewers who shared extensive comments on my earlier manuscript drafts. I also thank Professor Shigehisa Karimata for providing access to the digitized language data. Without their help, this paper could not have been completed.

2) Some researchers consider Yonaguni a separate primary branch (Kokuritsu Kokugo Kenkyūjo 2001: 15; Miyara 2011: 14, 2015: 176).

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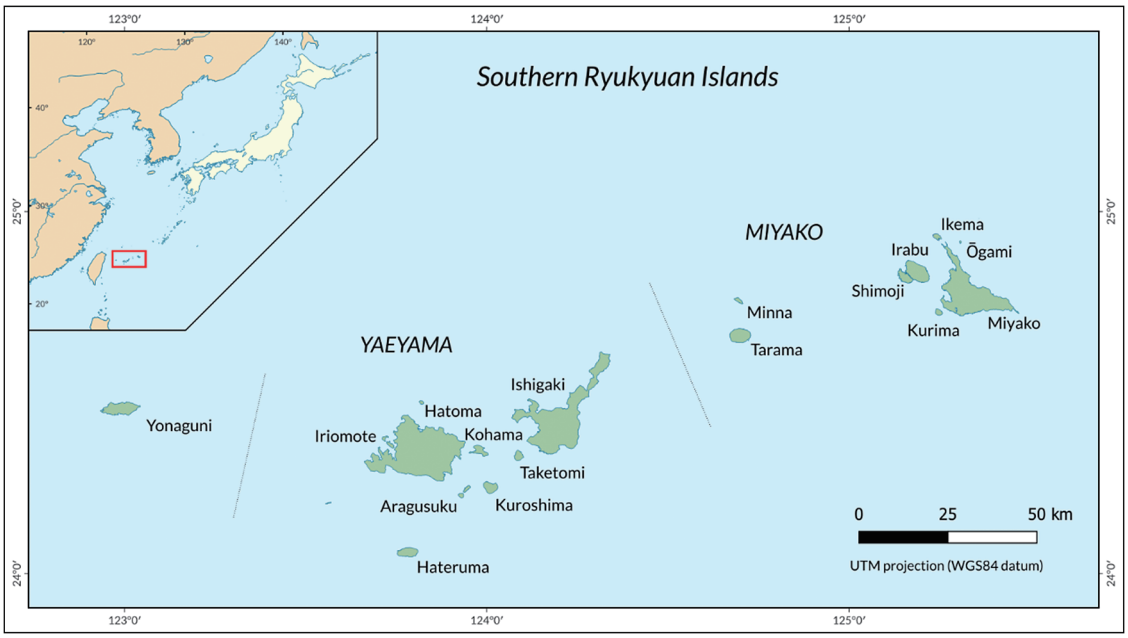
Received 29 September 2023
Accepted 7 December 2023

Appendix A Phonetic environments of analyzed sounds and vowels in relation to preceding phones

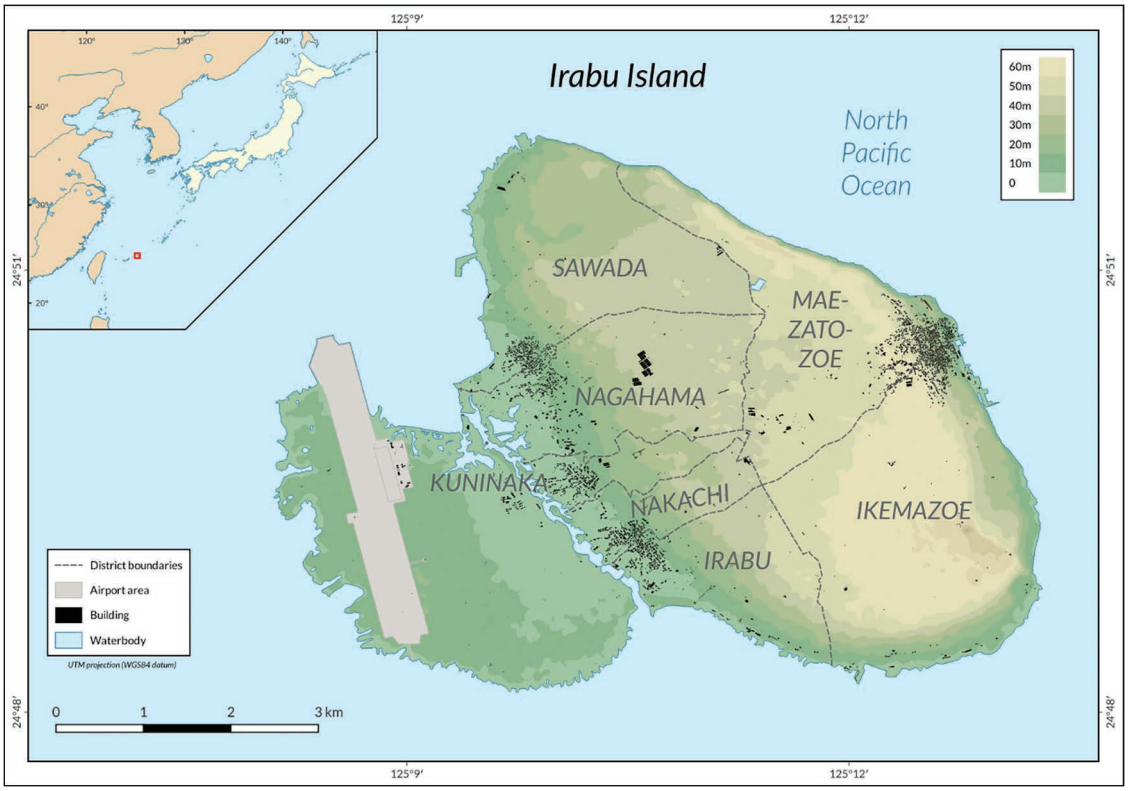
	i	iː	ɨ	ɨː	ɪ	ɪː	ʂ	ɑ̟	ɑ̟ː	u	uː	ʊ	ʊː	e̞	e̞ː	o̞	o̞ː
ɑ̟_	1437	2	1	0	1299	0	0	41	1	89	0	1	0	0	0	0	0
k_	1428	177	4	0	0	0	0	2796	206	3	1	1470	87	4	0	7	168
m_	1420	300	1	0	6	2	0	2105	269	1810	23	0	0	2	4	12	51
ɾ_	1173	41	0	0	0	0	0	1611	64	595	14	0	4	6	1	7	50
n_	827	212	0	0	2	0	0	1983	153	2133	96	0	0	5	3	28	189
e̞_	745	211	3	0	0	0	0	157	23	67	63	0	0	13	0	2	108
#_	722	39	0	0	50	17	0	1308	53	1237	59	12	0	6	3	5	82
g_	677	135	1	0	0	0	0	1260	163	2	0	740	89	10	4	3	56
t_	590	314	9	0	0	0	0	1779	97	1223	78	0	0	17	4	10	136
b_	516	12	0	0	123	118	0	1117	88	641	74	0	1	2	2	4	60
d͡ʑ_	353	24	1	0	0	0	0	57	21	61	69	0	0	9	3	5	67
t͡ɕ_	333	5	0	0	0	0	0	90	49	26	38	0	2	0	1	3	43
d_	265	28	0	0	0	0	0	830	40	515	105	0	0	9	0	7	62
u_	256	5	0	0	650	0	0	26	1	28	0	0	0	1	0	0	1
p_	210	22	1	0	69	56	393	959	75	450	35	1	0	0	2	7	38
ʑ_	124	2	2	0	0	0	0	19	8	3	0	0	0	0	0	0	0
h_	117	23	0	0	0	0	0	815	65	72	2	0	0	4	1	5	49
ʊ_	102	0	0	0	50	0	0	8	0	2	0	0	0	0	0	0	0
t͡ɕː_	94	0	0	0	0	0	0	42	12	5	2	0	0	0	0	0	2
v_	39	0	0	0	1	0	0	109	2	3	0	0	0	0	0	0	0
ɑ̟ː_	31	1	0	0	141	0	0	5	0	10	0	0	0	0	0	0	0
i_	29	0	0	0	1266	0	0	91	8	51	1	0	0	1	0	1	11
o̞ː_	21	2	0	0	68	0	0	4	1	5	0	0	0	0	0	0	2
f_	20	0	0	0	0	0	0	227	17	1469	110	0	0	0	0	1	14
e̞ː_	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ɨ_	12	1	0	0	6	0	0	30	2	26	0	0	0	0	0	0	0
uː_	11	0	0	0	68	0	0	16	0	1	0	0	0	0	0	0	0
ʔ_	8	0	6	0	7	0	0	630	13	4	2	0	0	2	0	49	4
z_	5	1	1060	143	0	0	0	376	18	115	92	0	0	0	0	0	49
o̞_	4	0	0	0	0	0	0	1	0	1	0	0	0	0	0	4	1
iː_	4	0	0	0	10	0	0	10	0	9	0	0	0	0	0	0	0
s_	4	0	2653	73	1	7	0	1255	45	607	58	0	0	0	0	17	66
ʊː_	2	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0
t͡s_	2	0	2590	147	0	0	0	50	1	60	31	0	0	0	0	0	0
ɪ_	2	0	0	0	1	0	0	10	1	6	1	0	0	0	0	0	0
d͡zː_	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
ɨː_	1	0	0	0	0	0	0	5	0	1	0	0	0	0	0	0	0
l_	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
vː_	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
d͡z_	0	0	71	35	0	0	0	42	8	9	23	0	0	0	0	1	44
t͡sː_	0	0	4	0	0	0	0	107	6	42	0	0	0	0	0	0	3
j_	0	0	0	0	0	0	0	1358	955	695	257	0	0	0	1	21	246
ɒ̟_	0	0	0	0	0	0	0	218	92	0	0	0	0	0	0	0	1
ŋ_	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0

Appendix B Phonetic environments of analyzed sounds and vowels in relation to following phones

	i	iː	ɨ	ɨː	ɹ	ɹː	ʂ	ɑ̟	ɑ̟ː	u	uː	ʊ̟	ʊ̟ː	e̞	e̞ː	o̞	o̞ː
_#	3488	706	2723	229	2671	113	0	2940	1109	2813	411	458	79	10	14	35	511
_ɹ	1266	10	6	0	1	0	0	1299	141	650	68	50	4	0	0	0	68
_k	825	50	731	15	140	5	45	961	84	956	107	69	5	0	0	7	88
_m	775	55	744	10	146	18	0	2601	88	1097	108	226	6	3	0	10	87
_n	647	147	341	20	92	12	1	1350	139	1416	44	177	3	19	7	14	60
_ŋ	480	117	87	2	9	0	1	466	26	168	5	29	0	24	1	10	18
_g	470	47	311	15	105	2	0	683	47	472	62	59	20	4	1	2	48
_ɾ	429	29	56	9	0	0	0	1700	198	712	56	344	11	6	1	7	57
_b	362	30	221	13	41	2	0	608	40	244	36	72	5	4	1	2	62
_d	332	42	86	6	70	0	0	354	44	278	22	32	1	0	0	1	39
_t͡s	314	23	244	2	69	1	40	652	39	449	22	28	0	0	0	13	10
_s	298	13	22	5	34	4	69	1617	240	662	38	101	11	0	0	2	104
_z	290	17	129	20	158	5	0	500	29	212	55	55	0	0	0	2	57
_t	250	42	238	10	100	11	229	1037	32	477	30	160	6	2	1	7	49
_j	218	99	93	5	24	3	0	409	47	268	42	35	13	1	1	1	80
_ɐ	196	22	8	0	11	0	0	277	37	131	27	42	2	1	0	12	54
_v	166	6	53	1	9	2	0	281	13	76	5	13	5	0	0	0	25
_f	154	15	94	9	50	8	3	268	35	168	24	22	1	0	0	5	43
_p	114	32	93	11	30	5	1	197	21	275	13	61	4	0	1	0	13
_t͡ɕ	94	4	8	0	2	0	0	85	13	67	3	18	3	0	0	1	15
_ɑ̟	91	10	30	5	10	0	0	41	5	26	16	8	0	0	0	1	4
_d͡ʑ	70	15	2	1	7	1	0	133	5	32	13	33	1	0	1	2	34
_u	51	9	26	1	6	0	0	89	10	28	1	2	0	0	0	1	5
_ʊ̟	43	3	2	1	2	0	0	60	2	39	2	5	0	0	0	0	5
_h	37	4	0	0	0	0	0	660	63	14	6	6	0	0	0	2	38
_i	29	4	12	1	2	0	0	1437	31	256	11	102	2	15	0	4	21
_t͡sː	27	2	22	0	0	0	2	55	2	33	1	4	0	0	0	0	1
_ʑ	22	2	1	4	18	6	0	74	4	10	0	2	0	0	0	0	0
_t͡ɕː	15	1	9	1	2	1	2	52	1	21	3	9	0	0	0	1	0
_o̞ː	11	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	2
_ɑ̟ː	8	0	2	0	1	0	0	1	0	1	0	0	0	0	0	0	1
_vː	8	0	3	0	0	0	0	3	1	3	2	0	1	0	0	0	0
_ʔ	7	1	7	0	8	1	0	633	9	6	0	0	0	2	0	52	1
_l	6	0	0	0	0	0	0	7	0	6	0	2	0	0	0	0	0
_d͡z	5	0	2	2	3	0	0	12	2	2	0	0	0	0	0	0	1
_uː	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
_e̞	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
_mː	1	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0
_o̞	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0
_iː	0	0	1	0	0	0	0	2	1	5	0	0	0	0	0	0	2
_d͡zː	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0
_ʊ̟	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
_ɨ	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0



Map 1 Main islands of southern Ryūkyū



Map 2 Districts of Irabu Island